# Big elephant data: analysis of 15 years of tracking across Africa

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## Abstract

Movements from two extant species of African elephant were studied using GPS tracking over a 15-year period in four distinct ecoregions: Desert, Savannah, Bushveld and Forest. These data were studied in relation to a series of environmental covariates to better understand the ranging behaviour of elephants across the continent and under diverse conditions. The magnitude of data and geographical extent required development of new software to calculate range metrics and couple them with covariate values. Human presence and protected areas were both important factors in modeling elephant range using mixed effects models and these results contribute new information to the conservation and ecology of elephants.

## Background and Relevance

African elephants (*Loxodonta africana* and *L. cyclotis*) are a particularly important species for geospatial study. Elephant movements and home ranges are extensive and among the largest of terrestrial mammals in Africa (Lindeque and Lindeque 1991, Wall et al. 2013). Protecting their needs for space has become a conservation challenge, especially in the face of the rapidly expanding human footprint (HF) across Africa (Sanderson et al. 2002). More acutely, a recent resurgence in the illegal killing of elephants for their ivory tusks has resulted in an estimated 100,000 animals killed between 2010-2012 (Wittemyer et al. 2014). From an ecological perspective, elephants are also the largest extant terrestrial mammals, known as megaherbivores (Owen-Smith 1988), who can directly shape their environments and their movement patterns tie directly to their role as ecosystem engineers (Western 1989).

Using GPS tracking we followed the movements of elephants across Africa over a 15-year period and in four distinct ecoregions: Desert, Savannah, Bushveld and Forest, in order to better understand elephant ranging behaviour in diverse conditions. Data collection was made by Save the Elephants, Kenya as part of an ongoing program to protect and understand the movement behaviour of elephants (Wall et al. 2014). Our study is based on the largest database of elephant movement currently available and required development of new geospatial analysis software and approaches.

## Methods and Data

GPS tracking data were collected from 226 elephants between 1998 to 2013 from five countries: Kenya, South Africa, Mali, Congo and Gabon representing four regional study areas (West, Central, East, South). We first estimated the 95% isopleth home-range areas for all elephants using the adaptive local convex hull (aLoCoH) method (Getz et al. 2007) over short, 16-day moving time windows using specially developed tools (available as part of the Movement Ecology Tools for ArcGIS software package (Wall 2014)). We then used emergent Google Earth Engine (GEE) technology (a cloud-based, remote sensing analysis platform:

https://earthengine.google.org), to extract and calculate covariates corresponding to each polygon area including the Normalized Difference Vegetation Index (NDVI), percent tree cover, HF, protected area intersection (PA), and slope among other covariates. We used both linear mixed effects and generalized additive mixed models to explore elephant ranging behaviour in relation to these factors.

## Results

Elephant range area was found to be highly variable and differ significantly between both sexes and across all four regions. We tested five hypotheses predicting elephant home range size under different conditions. Range area decreased with increasing human footprint and declined rapidly at a critical HF value past 35%. Elephants also displayed an edge-effect in relation to protected areas (PA) whereby range area decreased within PA, increased to a maximum at mid-range values of intersection with PA and decreased again for ranges occurring outside PA. Of the model covariates, Region and HF had the greatest effect on 16-day range areas.

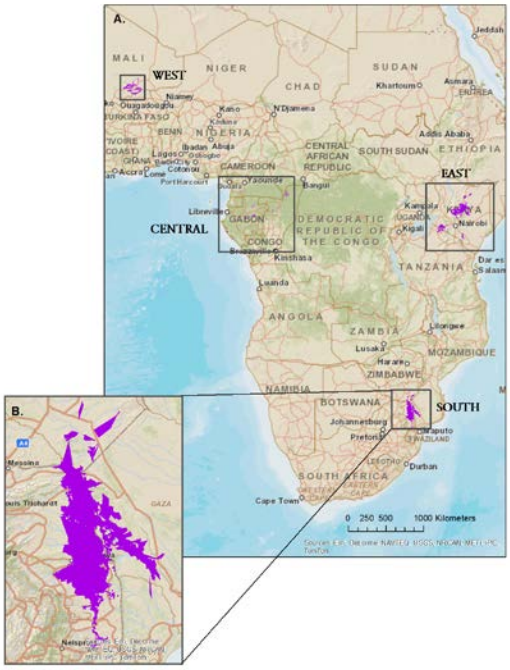


**Figure 1: A) Location of four regional study sites (West, Central, East, South) and B) detail of a-LoCoH 95% isopleth, 16-day elephant ranges in Southern Africa**

## Conclusions

Our study consolidates a large quantity of data on African elephant movement and uses these data to model elephant range over wide geographical gradients, across both extant species and in relation to a variety of covariates representative of the environmental extrema for the genera. The methods and results contribute significantly to the movement ecology and conservation of elephants as well as to the geospatial analysis of 'big' wildlife tracking data.

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